Can we-media information disclosure drive listed companies' innovation?—From the perspective of financing constraints

Hongbin Huang

School of Accounting, Tianjin University of Finance and Economics, Tianjin, China

Yani Sun

*School of Accounting, Tianjin University of Finance and Economics,
Tianjin, China, and*

Qingling Chu

Southwestern University of Finance and Economics, Chengdu, China

Abstract

Purpose – The purpose of this paper is to investigate to what extent the amount, information source and the content of the microblog information disclosure of listed companies could impact on innovation from the perspective of financing constraints.

Design/methodology/approach – The propensity score matching (PSM) and two-stage least square (2SLS) are used in estimations to deal with the endogeneity problem.

Findings – Evidence shows that the amount of we-media information disclosure significantly drives the innovation of enterprises. The mechanism is that we-media information disclosure drives the innovation by easing the financing constraints and bringing funds to the R&D activities. Further research shows that only the original information can drive the innovation. In particular, the R&D information promotes the R&D input and innovation output more significantly.

Practical implications – The conclusion of this paper provides a reference for the listed companies to drive innovation with the help of we-media information disclosure, a new solution for the small and medium-sized listed companies in China which have difficulty in carrying out innovation activities due to financing constrains and also provides useful practical enlightenment for the government and the capital market regulatory authorities to issue relevant policies to regulate we-media information disclosure.

Originality/value – This paper introduces a new information disclosure channel–we-media into the research on influencing factors of innovation and discusses the influence of the amount, different sources and disclosure contents from we-media on enterprise innovation, which enriches the existing research on enterprise innovation influencing factors, providing a new perspective for driving enterprises to innovate.

Keywords We-media, Microblog, Financing constraints, Innovation

Paper type Research paper

1. Introduction

Innovation is an indispensable driving force for economic development and social progress (Solow, 1957; Porter, 1992). In 2018, ZTE lost seven billion RMB due to the disruption of production caused by chip cut-off. However, Huawei passed the crisis due to the investment in R&D each year. It can be seen that technological innovation is an important factor affecting the future of an enterprise or even a country. However, the innovation activities of enterprises in China are often faced with financial constraints. Due to the characteristics of high risk and long R&D cycle (Hottenrott and Peters, 2012), it is far from enough to rely on internal financing, which requires a large number of sustained financial support from external financing (Xie and Fang, 2011; Brown, 2009).

Moreover, the innovation activities of enterprises are highly uncertain and difficult to be observed (Hottenrott and Peters, 2012; Manso, 2011). Because of the serious information

asymmetry caused by the little disclosure of R&D information from the enterprises for the sake of preventing competitors, the investors do not understand the operation status and R&D ability of enterprises (Saunders and Steffen, 2011), leading to a serious financing constraints. How to break the barriers of financing constraints to smoothly obtain financial support for high-quality R&D projects is a common concern in the existing academic and practical circles.

Based on this, we attempt to explore whether this information disclosure is conducive to innovation from a new perspective of we-media information disclosure, and further test its mechanism. Compared with prior research, we expect our study to contribute to the literature in several ways.

First, as an important measure to solve the shortage of innovation investment funds, reducing information asymmetry has been focused from the perspective of traditional information intermediaries in disseminating and mining information. This paper introduces a new information disclosure channel–we-media into the research on influencing factors of innovation and discusses the influence of the amount, different sources and disclosure contents from we-media on enterprise innovation, which enriches the existing research on enterprise innovation influencing factors, providing a new perspective for driving enterprises to innovate.

Second, the existing research on the economic consequences of we-media information disclosure mainly focuses on capital market, including the performance of the stock market, while it is relatively lacked in the research on the investment behavior of enterprises, especially on R&D investment. We discuss whether we-media information disclosure can drive innovation by relieving financing constraints, which provides new evidence for how we-media information disclosure plays an active role in corporate behavior.

Third, based on the finding that microblog information disclosure can promote enterprise innovation, this paper further analyzes and finds that original information and R&D-related information disclosure have more significant effects on driving enterprise innovation, which refines the impact of the source and content of we-media information disclosure on enterprise innovation and provides decision-making basis for listed companies to drive enterprise innovation with we-media.

2. Literature review and research hypothesis

2.1 Literature review

2.1.1 Economic consequences of we-media information disclosure. As a new way of information disclosure, we-media is different from traditional media. The economic consequences of enterprises using this way to disclose information mainly focus on the following two aspects:

One is on the capital market. Companies who disclose relevant information through Twitter could significantly reduce bid-ask spreads and increase liquidity (Blankespoor *et al.*, 2014; Balakrishnan *et al.*, 2014). Takeda (2006) found that the company's stock price continued to grow steadily after the broadcast. In addition, extensive voluntary disclosure is significantly related to stock prices (Chen *et al.*, 2017; Antweiler and Frank, 2004). Dhaliwal *et al.* (2011) and Chapman *et al.* (2018) empirically examined that nonfinancial disclosure could significantly improve the accuracy of earnings forecasts of analysts.

The other is on the corporate behavior. First, Teoh (2018) believed that "new" data from Twitter, providing new auditing tools to detect the possibility of bad financial reporting, which will help curb revenue management. Second, as early as 1997, Botosan found that information disclosure could ease financing constrains and improve business performance by obtaining sufficient financial support. Jung *et al.* (2018) found that firms with a larger social media audience always have higher incentives for strategic dissemination. Shroff *et al.* (2013) suggested that listed companies tend to disclose more information before equity financing under the background of "gun-jumping" regulation. Moreover, companies that do

not actively disclose will generate a large risk premium and the quality of information disclosure can affect the cost of capital through the company's future cash flow (Bertomeu and Cheynel, 2016; Mohamed, 2016; Efendi *et al.*, 2014; Gajewski and Li, 2015; Lambert *et al.*, 2007).

2.1.2 The driving factors of innovation. The research on the driving factors of innovation is divided into two aspects. The first one is the willingness of enterprises to innovate which mainly focuses on Corporate Governance, including equity concentration, management incentives, legal environment, product market competition and so on (Francis and Smith, 1995; Ederer and Manso, 2013; Brown *et al.*, 2013; Aghion *et al.*, 2002).

The second one is the ability of innovation. The prior literatures focus on reducing financing constraints for innovation by information disclosure. We can divide information disclosure into mandatory disclosure and voluntary disclosure (Bushman *et al.*, 2004). Mandatory disclosure is generally based on regulatory policies and regulations and is also the minimum requirement of corporate information disclosure. The internal control information and the disclosure of risk information in annual report improved the transparency of information and reduced the cost of debt capital (Chiu *et al.*, 2017; Hope *et al.*, 2014; Skaife *et al.*, 2007). Therefore, in order to reduce information asymmetry and meet the information needs of investors, companies usually choose voluntary disclosure as a useful supplement.

Goldstein and Yang (2017) and Kothari *et al.* (2009) confirmed that incremental information disclosure can affect capital cost by affecting perceived risk. Corporate social responsibility and environmental reporting information disclosure also help to reduce information asymmetry to affect capital costs (Richardson *et al.*, 1999; Dhaliwal *et al.*, 2011; Fondevila *et al.*, 2019; Inoue, 2016). Iatridis (2013) found that voluntary disclosure of environmental information can affect investors' perception, resulting in lower financing constraints than other enterprises. Moreover, Chen *et al.* (2014) found that corporate information disclosure through we-media promoted innovation. And in areas where the government is less protective of investors, it is more conducive to innovation.

2.1.3 Summary. Generally speaking, the research on the impact of information disclosure on the company mainly focuses on the capital market, while the combination of we-media information disclosure and enterprise innovation has not yet appeared.

Second, most scholars agree that information disclosure (financial information, social responsibility report, etc.) is conducive to improve the information transparency of enterprises, and thus relieve the financing constraints. We-media has many advantages over other information disclosure: it can not only repost the articles published by others but also release the new special information of the company. However, there are few literatures about we-media information disclosure of listed companies, and whether the differences of information source and disclosure content have different effects on innovation. This paper tries to carry out expansive research in this aspect.

2.2 Theoretical analysis and research hypothesis

As new information disclosure channels, microblog, WeChat and other we-media also create different information communication opportunities for listed companies (Blankespoor, 2018; Miller and Skinner, 2015). Compared with other voluntary information disclosure, the we-media information disclosure is more diversified, and its readability and interest are significantly higher than those of mainstream media and third-party professional interpretation. It requires less time and knowledge structure for investors, and it is easier to obtain and interpret information. It can adjust the value judgment of investors, change their cognition and expectation of enterprises and optimize the image of listed companies to enhance their reputation (Goldstein and Yang, 2017). Based on the information obtained from

we-media channels, investors can get a more comprehensive understanding of the company's situation and make more accurate pricing of equity and debt financing.

On the one hand, we-media channels provide more incremental information of the company to alleviate the information asymmetry between the enterprise and the outside. On the other hand, based on the signaling theory (Spence, 1973), enterprises can disclose continuous information to enhance the interaction with the outside through we-media channels, optimizing the reputation and image of the enterprise and becoming a strong positive signal to enhance the confidence of external investors (Nader, 2013). Therefore, we-media information disclosure can affect enterprise financing constrains through information and reputation mechanism (Huang *et al.*, 2020). Especially, when the enterprise continues to disclose information about the company's financing behavior, investment decisions, reputation awards and other value related information, external creditors and investors will have a more accurate understanding and prediction of the planning, operation and development of the enterprise, reducing the uncertainty of evaluation in the enterprise's future development and making investors more willing to provide support for the enterprise's development (Michelon, 2011).

R&D activities need more financing. The input and output of R&D activities need a lot of long-term financial support, while it cannot accurately quantify the input and output like the investment of a device (Xie and Fang, 2011; Hottenrott and Peters, 2012), which makes investors reduce the investment of such projects or require a higher risk premium (Hall, 2002). Only investors are willing to provide equity and debt funds for enterprises, can enterprises use more cash flow to carry out R&D activities or the enterprise will face with financing constrains (Myers and Majluf, 1984). Therefore, when enterprises disclose more we-media information to ease their financing constraints, they will invest more funds in their own R&D activities to create greater value for themselves. Given these arguments, we propose hypothesis 1:

  H1. We-media information disclosure can drive innovation of companies by relieving financing constraints.

3. Research design

3.1 Sample and data
We select the firms listed on two Chinese (Shanghai and Shenzhen) A-share stock markets over the 2009–2017 period, since microblog officially launched in 2009. In order to eliminate the adverse effects of abnormal samples on the results, we exclude firms in severe financial distress/undergoing bankruptcy, such as special treatment firms. We also exclude firms in the financial and insurance sector because the financial statements in these sectors differ greatly from those in other sectors in China. Next, we remove samples with missing financial data. Lastly, all continuous variables are winsorized at the 1st and 99th percentiles, yielding 3905 firm-year observations. We collect all our samples from the CSMAR and WIND databases, and the data of we-media information disclosure on microblog and Wechat are obtained by computer crawler technology.

3.2 Variables measures
3.2.1 Innovation. Following the prior literature, we employ both ex ante and ex post measures to proxy the innovation from the perspective of R&D input and R&D output of listed firms. According to Sapra *et al.* (2014) and Xie and Fang (2011), we use R&D intensity-R&D expenditures, the ratio of a firm's R&D expenditures to operating revenue and the ratio of a firm's R&D expenditures to total assets as our ex ante measure . The larger the value, the

higher the R&D intensity. The natural logarithm of the total number of patent applications in the $T+1$ year plus 1 is used to measure the innovation output level of enterprises (Cornaggia *et al.*, 2015; Fang *et al.*, 2014).

3.2.2 Information disclosure on microblog. Microblog, Wechat Official Account and company website are the main we-media channels used by listed companies. We choose microblog as the representative of we-media in the basic regression because it is most widely used by listed companies.

We use Internet search technology and computer text analysis technology to obtain microblog disclosure information. First, according to the name, abbreviation, former name and company code of the listed company, there are 1436 listed companies that have opened official microblog, accounting for 39.37% of all listed companies before December 31, 2018. The number of microblog opened by listed companies, industries and regions are shown in Table 1.

This paper uses *MB* as the independent variable to measure the logarithm of the total amount of information disclosed by microblog of listed companies. To investigate the impact of the content of we-media information on innovation, we classify our data in detail as follows:

Step 1: Data collection

From October 2009 to December 2018, all the information disclosed by the official microblog of all the listed companies that have opened the official microblog is crawled down by Python, including original and reposting. The final data contain 2,443,426 pieces of microblog information.

Step 2: Construction of microblog content classification

First, we classified all microblog content by manual reading, including performance, financing, marketing, research and development, new product, investment, reputation, social responsibility, corporate culture, government and policy, ownership reform and corporate governance and others; Second, we use Jieba, a kind of Chinese word segmentation tool, to generate a directed acyclic graph of all possible word formation situations of Chinese characters in sentences; we also use HMM model based on the word formation ability of Chinese characters and Viterbi algorithm for unregistered words. After segmenting the data, a total of 195,988 words were generated, forming the basic vocabulary. In order to improve the accuracy, we asked 11 subjects (11 graduate students) to mark the basic vocabulary and classified the appropriate vocabulary into the above 12 categories. (See Section 6 for the specific classification results).

3.2.3 Control variables. To control other effects on innovation, we include in our regression models the set of standard control variables that are used in the literature (Wu and Huang, 2017; Bernstein, 2015): firm size (*Size*), financial leverage (*Lev*), growth opportunity (*Growth*), years of establishment (*AGE*), profitability (*ROA*) and net cash flow from operating activities (*CF*). In addition, we also control whether the general manager and the chairman of the board of directors are dual (*DUAL*), the proportion of independent directors (*INDEP*) and the influence of corporate governance factors, such as the ownership concentration (*HHI*), shareholding ratio of the largest shareholder (*Top1*), separation rate of two rights (*Separation*), proportion of R&D staff (*RDPERSON*) and the influence of external environmental factors, such as government subsidies(*SUBSIDY*) and market-oriented index (*MP*). Meanwhile, we also specifically add the number of listed companies reported by mainstream media (*Lntitle*) to control the impact of other information disclosure channels on enterprise innovation. Finally, a year (*Year*) dummy variable and industry (*Industry*) dummy variable are also included in our study to control for the differences in firm innovation that exist in different industries (See Table 2 for definitions of main variables).

Table 1.
The statistics of China listed companies open the official microblog quantity

Panel A: Annual statistics

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Subtotal
Open official microblog	13	118	338	294	230	140	117	67	80	39	1436
No official microblog	3580	3462	3124	2830	2600	2460	2343	2276	2196	2157	2157
Opening ratio	0.36%	3.30%	9.76%	9.41%	8.13%	5.38%	4.76%	2.86%	3.51%	1.78%	39.97%

Panel B: Industry statistics

Industry	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Q	R	Subtotal
Open official microblog	13	13	847	25	34	88	32	7	161	46	47	30	20	22	5	46	1436
No official microblog	28	64	1434	84	62	77	72	2	108	51	76	22	33	27	5	12	2157
Opening ratio	31.7%	16.9%	37.13%	22.94%	35.42%	53.33%	30.77%	77.78%	59.9%	47.42%	38.21%	57.69%	37.74%	44.90%	50.00%	79.31%	39.97%

Panel C: Regional statistics

Region	AnHui	Beijing	Chong Qing	FuJian	GanSu	Guang Dong	GuangXi	GuiZhou	HaiNan	HeBei	HeNan	HeiLongLing	HuBei	HuNan	JiLin	JiangSu	JiangXi
Open microblog	47	136	24	56	18	261	10	8	14	20	35	16	42	38	11	144	12
No microblog	58	186	28	71	11	352	29	20	19	37	41	19	61	59	27	247	32
Opening ratio	44.76%	42.24%	46.15%	44.09%	62.07%	42.58%	25.64%	28.57%	42.42%	35.09%	46.05%	45.71%	40.78%	39.18%	28.95%	36.83%	27.27%

Region	Liao Ning	Nei Menggu	NingXia	QingHai	Shan Dong	ShanXi	Shang Hai	ShaanXi	Si Chuaug	TianJin	XiZang	Xin Jiang	YunNan	Zhe Jiang	Subtotal
Open microblog	27	9	6	6	76	11	118	24	42	20	8	19	8	170	1436
No microblog	45	18	9	8	122	24	161	27	85	33	10	36	22	260	2157
Opening ratio	37.50%	33.33%	40.00%	42.86%	38.38%	31.43%	42.29%	47.06%	33.07%	37.74%	44.44%	34.55%	26.67%	39.53%	39.97%

Panel D: The statistics of the official Weibo opening time

Open microblog before IPO	506	31.35%
Open microblog after IPO	930	68.65%

Panel E: The statistics of company's property nature

State-owned companies	479	33.36%
Private companies	957	66.64%

Note(s): The industry classification is based on the industry classification guideline of China's listed companies (revised in 2012); A represents agriculture, forestry, animal husbandry and fishery; B represents mining; C represents manufacturing; D represents electricity, heat, gas, water production and supply; E represents construction; F represents wholesale and retail; G represents transportation, warehousing and postal services; H represents lodging and catering; I represents information delivery, software and IT services; J represents real estate; K represents leasing and business services; L represents scientific research and technology services; M represents water, environment and public facilities management; N represents health and social work; Q represents culture, sports and entertainment

Variable	Description	Abbreviation	Measurement
Dependent variable	Innovation	*RDSALE*	Proportion of R&D investment in operating income
Independent variable	The amount of microblog disclosure	*MB*	The natural logarithm of the total amount of information disclosed by microblog plus 1
	The amount of various content	*LNONE— LNTWELVE*	The natural logarithm of each content of information disclosed by microblog plus 1
	The amount of original information	*MBYC*	The natural logarithm of original information of information disclosed by microblog plus 1
	The amount of reposting information	*MBZF*	The natural logarithm of reposting information of information disclosed by microblog plus 1
Grouping variable	*KZ* index	*KZ*	−6.315*net cash flow from operating activities −39.356*(pre-tax cash dividends per share *outstanding shares)/*SIZE*-3.494*balance of cash and cash equivalents at the end of the period/*SIZE*+3.291**LEV*+0.460*Tobin *Q*
	WW index	*WW*	−1.002*net cash flow from operating activities/the natural logarithm of net fixed assets-39.368*(pre-tax cash dividends per share *outstanding shares)/ the natural logarithm of net fixed assets-1.315*balance of cash and cash equivalents at the end of the period/ the natural logarithm of net fixed assets+3.139**LEV*+ 0.283*Tobin *Q*
	State of property right	*State*	Value 1 for state-owned enterprises; 0 for non-state-owned enterprises

Table 2.
Variable definition and measurement

3.3 Empirical model
We examine the relation between the information disclosure on microblog with innovation using the following base regression models:

$$RDSALE_{i,t} = \alpha_0 + \alpha_1 MB_{i,t} + \sum \alpha_k (Control + IND + YEAR) + \varepsilon \qquad (1)$$

where *RDSALE* is the degree of corporate innovation measured by the ratio of R&D investment to operating revenue. The higher the value, the more innovation can drive. *MB* represents the amount of information disclosed by the enterprises. In the model (1), if the information disclosure of microblog can drive enterprise innovation, the coefficient α_1 of *MB* should be significantly greater than 0. *Control* stands for control variables mentioned above.

Considering the listed companies' information disclosure through we-media can drive the innovation by reducing financing constraints. We set financing constraints into different groups. Following Wei *et al.* (2014), White and Wu (2006) and Hadlock and Pierce (2010), we select *KZ* index(calculated with the operating net cash flow, dividend, cash holding, asset liability ratio and Tobin *Q* of the companies listed in China), *WW* index and property right with Chinese characteristic as the grouping variables from three different dimensions. The larger the *KZ* index, the higher the degree of financing constraints, and the same is for *WW* index. Therefore, we group them according to the mean value of *KZ* and *WW* index. The degree of financing constraint equals 1 if the *KZ* and *WW* index is higher than the median of our sample, namely high financing constraint group, and 0 otherwise, namely low financing constraint group. For the state of property rights, private-listed companies are defined as high financing constraint group (value 0), while state-owned listed companies are defined as low financing constraint group (value 1).

4. Empirical test and analysis

4.1 Descriptive statistics

The descriptive statistics of the variables in our regression analysis can be seen in Table 3. The maximum of amount of microblog disclosure (*MB*) is 7.111, the minimum is 0 and the SD is 1.965, indicating that there are significant differences in the amount of microblog disclosure in different companies. The maximum of *RDSALE* is 0.223, the minimum is 0 and the SD is 0.039, which shows there are obvious differences in innovation ability and willingness of companies. There is no significant difference between the descriptive statistical results of other variables and the previous studies.

Table 4 presents the descriptive statistics of grouping variables. Taking the results of *KZ* index as the grouping variable of financing constraints as an example, the *RDSALE* in high

Variable	N	Mean	Sd	min	p25	Median	p75	max
MB	3905	0.992	1.965	0	0	0	0	7.111
RDSALE	3905	0.044	0.039	0	0.021	0.035	0.053	0.223
Patent	3905	3.497	1.369	0.693	2.565	3.466	4.357	7.319
SIZE	3905	22.38	1.192	20.24	21.54	22.23	23.05	26.24
Age	3905	16.80	5.130	7	13	17	20	31
CF	3905	0.044	0.063	−0.137	0.007	0.042	0.082	0.224
LEV	3905	0.414	0.185	0.064	0.269	0.410	0.556	0.828
GROWTH	3905	0.226	0.414	−0.382	0.008	0.135	0.325	2.445
ROA	3905	0.045	0.041	−0.073	0.018	0.037	0.066	0.184
HHI	3905	0.152	0.104	0.018	0.075	0.124	0.201	0.520
Top1	3905	33.73	13.91	9.030	23.08	31.99	42.63	71.24
Separation	3905	4.520	7.282	0	0	0	7.354	26.65
INDEP	3905	0.375	0.054	0.333	0.333	0.333	0.429	0.571
DUAL	3905	0.275	0.447	0	0	0	1	1
RDPERSON	3905	14.90	12.22	0.413	7.024	12.07	18.21	64.20
SUBSIDY	3905	0.006	0.007	0	0.002	0.004	0.007	0.038
MP	3905	8.395	1.831	1	7.09	9.150	9.86	10
LNtitle	3905	1.598	1.052	0	0.693	1.609	2.303	4.533

Table 3.
Descriptive statistical of main variables

	High financing constraint		Low financing constraint			
	Mean	Median	Mean	Median	*T*-test	Rank sum test
Table 1: Financing constraint indicator – KZ index						
RDSALE	0.028	0.024	0.048	0.038	−12.68***	−15.78***
MB	1.544	0	0.857	0	8.759***	6.980***
WC	2.821	3.258	2.372	2.565	4.791***	4.884***
Table 2: Financing constraint indicator – WW index						
RDSALE	0.033	0.029	0.053	0.041	−16.198***	−18.52***
MB	1.165	0	0.852	0	4.973***	3.734***
WC	2.722	3.178	2.249	2.303	6.331***	6.512***
Table 3: Financing constraint indicator – State						
RDSALE	0.033	0.029	0.049	0.038	−11.811***	−14.87***
MB	1.013	0	0.947	0	0.980	2.331***
WC	2.506	2.833	2.364	1.792	1.792*	1.646**
Note(s): ***, ** and * represent significance level of 1%, 5% and 10%, respectively						

Table 4.
Descriptive statistics of variables grouped by financing constraints

financing constraint group is lower than that in low financing constraint group at 1% level both in average and median, and the amount of information disclosure on microblog and WeChat is significantly higher than that in low financing constraint group, which initially suggests that financing constraints significantly restricts the innovation activities of enterprises and enterprises with high financing constraints are willing to disclose more information. The analysis of grouping variables with *WW* index and *State* is similar. The three grouping variables are effective for the grouping of financing constraints through *t*-test and rank sum test.

4.2 Analysis of regression

4.2.1 The overall effect of we-media information disclosure on innovation. Column (1) in Table 5 shows the overall impact of we-media information disclosure from listed companies on enterprise innovation. The regression coefficient of *MB* is significantly positive at the 1% level, suggesting the amount of annual microblog disclosure is significantly positively related to the R&D investment of enterprises, indicating that we-media information disclosure by microblog of listed companies can significantly drive enterprise innovation, partially supporting the hypothesis H1.

4.2.2 Mechanism analysis. We examine the influence mechanism grouped by financing constraints. If the microblog information disclosure has a greater driving force for innovation when the financing constraints are high, it can verify the hypothesis. In this paper, *KZ* index, *WW* index and *State* are selected as grouping variables (see Table 3 for definitions of grouping variables).

As shown in column (2)–(7) in Table 5, in the group with higher financing constraints, the coefficients of *MB* are significantly positive at the 1 and 5% level, respectively, while in the group with lower financing constraints, the regression coefficients of *MB* are not significant. The results suggest that, the more serious the financing constraints, the greater role the microblog information disclosure plays in driving innovation, which shows that in enterprises with higher financing constraints, the microblog information disclosure alleviates the degree of information asymmetry of such enterprises, making the innovation projects of such enterprises known to more investors which provides more financing facilities to drive enterprise innovation, the mechanism is established.

5. Robustness test

We conduct six tests to verify the robustness of our results. First, in order to avoid the bias caused by endogeneity on empirical results, we use the propensity score matching (PSM) and choose the exogenous variable of urban Internet development level (City10) as the tool variable to conduct two-stage least square (2SLS). Second, we develop an alternative measure (*WC*) for information disclosure of microblog, and we use the lag of information of microblog in the regression model (2). Then, we develop an alternative measure (*RDASSET*) for R&D investment. In addition, we select *SA* index and *KZ1997* index as alternative measures for grouping variables. Finally, we employ continuous variables of financing constrains in regression analysis instead of grouping. The results remain consistent with the main findings.

5.1 Propensity score matching

There may be a concern of self-selection whether enterprises open microblog or not may affect the tests. Thus, this paper uses the method of year by year propensity score matching (PSM) to solve the possible endogenous problems. The experimental group is the companies that opened microblog, while the control group is those that did not open microblog.

	(1) RDSALE	(2) KZ = 1	(3) KZ = 0	(4) WW = 1	(5) WW = 0	(6) State = 0	(7) State = 1
MB	0.001*** (2.65)	0.001*** (3.20)	0.000 (0.08)	0.001*** (3.24)	0.001 (1.36)	0.001** (2.57)	0.000 (0.73)
SIZE	-0.002** (-3.02)	-0.002** (-2.52)	-0.002 (-1.43)	-0.001 (-0.69)	-0.002** (-2.05)	-0.001 (-1.25)	-0.003** (-2.57)
Age	-0.000** (-2.55)	-0.000*** (-2.74)	-0.000 (-0.38)	-0.000*** (-2.68)	-0.000 (-0.90)	-0.000 (-1.22)	-0.001*** (-3.16)
CF	0.006 (0.62)	0.010 (0.85)	-0.047** (-2.02)	0.012 (0.90)	-0.002 (-0.15)	0.012 (1.02)	-0.005 (-0.34)
LEV	-0.036*** (-8.17)	-0.036*** (-7.28)	-0.029*** (-4.07)	-0.044*** (-7.04)	-0.024*** (-4.51)	-0.040*** (-7.09)	-0.025*** (-3.65)
GROWTH	-0.005** (-4.00)	-0.006*** (-3.85)	-0.002 (-0.81)	-0.006** (-2.15)	-0.004** (-2.75)	-0.006** (-3.61)	-0.003* (-1.71)
ROA	-0.085** (-4.79)	-0.102*** (-5.08)	-0.001 (-0.02)	-0.129*** (-5.22)	-0.020 (-0.86)	-0.117*** (-5.35)	-0.028 (-0.93)
HHI	-0.008 (-0.42)	-0.010 (-0.42)	-0.009 (-0.32)	-0.017 (-0.58)	-0.013 (-0.64)	-0.014 (-0.58)	0.015 (0.51)
Top1	-0.000 (-0.47)	-0.000 (-0.29)	-0.000 (-0.38)	-0.000 (-0.12)	0.000 (0.03)	0.000 (0.28)	-0.000 (-1.29)
Separation	0.000*** (2.29)	0.000* (1.69)	0.000 (1.28)	0.000 (1.37)	0.000 (1.62)	0.000 (0.72)	0.000** (2.41)
INDEP	0.032*** (2.81)	0.033** (2.61)	0.028 (1.39)	0.033** (2.13)	0.026 (1.64)	0.043*** (2.74)	0.015 (0.98)
DUAL	0.004** (2.43)	0.003* (1.94)	0.006* (1.96)	0.003* (1.75)	0.004* (1.95)	0.003* (1.86)	0.004 (1.16)
RDPERSON	0.001*** (11.91)	0.001*** (11.25)	0.001*** (5.36)	0.001*** (10.26)	0.001*** (8.24)	0.001*** (10.20)	0.001*** (6.52)
SUBSIDY	1.144*** (7.75)	1.280*** (7.32)	0.691* (4.16)	1.299*** (7.10)	0.870*** (4.55)	1.311*** (7.09)	0.825*** (3.37)
MP	0.000 (0.89)	0.000 (0.48)	0.001* (1.83)	0.000 (0.08)	0.001** (2.12)	-0.000 (-0.22)	0.001** (2.03)
LNhtle	0.001* (1.78)	0.001 (1.52)	0.001 (1.17)	0.001 (1.24)	0.001 (1.25)	0.001 (1.41)	0.001 (1.05)
_cons	0.051*** (3.08)	0.060*** (2.62)	0.046 (1.45)	0.032 (0.87)	0.058** (2.64)	0.034 (1.42)	0.074** (2.30)
N	3905	3140	765	2161	1744	2639	1266
R^2	0.522	0.504	0.525	0.511	0.477	0.507	0.520

Note(s): ***, ** and * represent significance level of 1%, 5% and 10%, respectively. T-value is in brackets, and standard error is adjusted by cluster at company level, the same below

Table 5.
Basic regression and influence mechanism test

Through the PSM to match whether to open microblog, we finally select *ROA, SIZE, AGE, CF, DUAL and SUBSIDY* as covariates. The matched samples include 2041 annual observations of the experimental group and the control group. The multivariate *t*-test of matched group samples shows that there is no significant difference between the control group and the experimental group in terms of these covariates, meeting the balance test. The test results are shown in Table 6.

Column (1) in Table 7 reports the overall impact of we-media information disclosure of listed companies on innovation, and columns (2) to (7) test the mechanism. The results show that after controlling the endogeneity, the results are consistent with the basic regression results. Hypotheses 1 is further supported.

5.2 Two-stage least square (2SLS)

Though we take the companies who open official microblog as the control group and look for those who do not open official microblog as matched group, which avoids the endogenous influence to a certain extent, the endogenous problem caused by mutual causation may still exist. We use the two-stage least square (2SLS) to deal with it. According to Yang and Liu (2018), we choose the urban Internet development level as the instrumental variable (*City10*) of independent variable. If the city where the listed company is located is one of the 10 cities with the best Internet development, it equals 1, 0 otherwise. As shown in Table 8, column (1) reports the regression result of the first stage, the coefficient of instrumental variable (*City10*) is significantly positive with independent variable (*MB*) and the F value of weak instrumental

Covariates	Unmatched/ Matched	Experimental group	Control group	% Bias	T-Value	P value
ROA	U	0.0493	0.0377	27.100	4.800	0.000
	M	0.0491	0.0490	0.3000	0.050	0.958
SIZE	U	22.280	22.150	11.00	1.960	0.050
	M	22.277	22.213	5.400	0.890	0.372
Age	U	15.636	16.231	−11.80	−2.090	0.037
	M	15.652	15.612	0.800	0.130	0.898
CF	U	0.0553	0.0443	18.40	3.250	0.001
	M	0.0552	0.0508	7.300	1.170	0.243
DUAL	U	0.3116	0.2384	16.40	2.910	0.004
	M	0.3122	0.2940	4.100	0.650	0.513
SUBSIDY	U	0.0068	0.0052	24.90	4.450	0.000
	M	0.0067	0.0070	−4.100	−0.600	0.546

Table 6. The balance test of PSM (take 2015 as an example)

	(1) RDSALE	(2) KZ = 1	(3) KZ = 0	(4) WW = 1	(5) WW = 0	(6) State = 0	(7) State = 1
MB	0.001**	0.001***	−0.000	0.002***	0.001	0.001**	0.001
	(2.54)	(2.94)	(−0.08)	(2.99)	(1.20)	(2.42)	(0.87)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
YEAR/ IND	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2041	1639	402	1132	909	1421	620
R²	0.525	0.511	0.493	0.535	0.432	0.516	0.523

Table 7. PSM robustness test

variable test is 18.76, indicating that it is not a weak instrumental variable. The second regression result is shown in column (2), which is consistent with the main regression result.

5.3 Alternative measure of the independent variable
As another we-media channel, WeChat Official Account is widely used by listed companies in recent years. As of December 31, 2018, there were 2275 listed companies opening WeChat Official Account, accounting for 62.86% of all listed companies. The opening time is shown in Figure 1.

Therefore, we take the natural logarithm of the amount of WeChat Official Account information disclosure plus 1 (*WC*) as the alternative variable, and we repeat the regression tests. As shown in Table 9, *WC* is significantly positive at the 5% level, and the mechanism test is consistent with the regression results of *MB*.

In addition, considering the impact of information disclosure of microblog on the innovation is not contemporaneous. We use the lag of information disclosure of microblog

	(1) *MB*	(2) *RDSALE*
MB		0.001*** (2.65)
City10	0.205*** (2.81)	0.037*** (2.61)
Control	Yes	Yes
YEAR/IND	Yes	Yes
N	3770	3770
R^2	0.099	0.099

Table 8.
2SLS robustness test

Figure 1.
The opening time and quantity distribution of WeChat Official Account

	(1) *RDSALE*	(2) *KZ* = 1	(3) *KZ* = 0	(4) *WW* = 1	(5) *WW* = 0	(6) *State* = 0	(7) *State* = 1
WC	0.001**	0.001**	−0.000	0.001***	−0.000	0.001*	0.000
	(2.09)	(2.01)	(−0.49)	(2.72)	(−0.91)	(1.94)	(1.15)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
YEAR/IND	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	3905	3140	765	2161	1744	2639	1266
R^2	−0.668	−0.754	−1.110	−0.881	−0.872	−0.648	−0.697
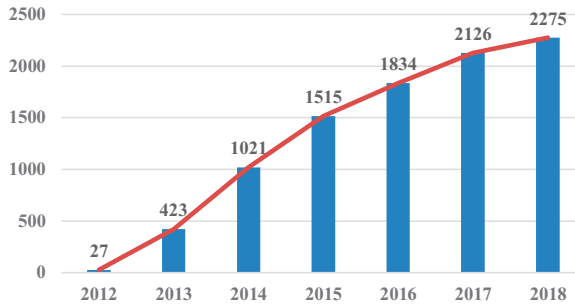
Table 9.
Replace the independent variable with *WC*

(MB_{t-1}) to replace the independent variable in the model (2) to solve this problem as follows:

$$RDSALE/RDASSET/Patent_{i,t} = \alpha_0 + \alpha_1 MB_{i,t-1} + \sum \alpha_k (Control + IND + YEAR) + \varepsilon$$
(2)

As shown in Table 10, MB_{t-1} is significantly positive with innovation input (*RDSALE/RDASSET*) at the 1% level, and with innovation output (*Patent*) at the 5% level.

5.4 Alternative measure of the dependent variable and grouping variables

We replace the dependent variable with the proportion of R&D investment in the total assets of enterprises (*RDASSET*) and repeat the regression tests. The results are shown in Table 11. According to Hadlock and Pierce (2010) and Kaplan and Zingales (1997), we also replace the grouping variables with *SA* index (constructed by the financial indicators of enterprise scale and age, with strong exogeneity) and *KZ* 1997 index (calculated with the operating net cash flow, dividend, cash holding, asset liability ratio and Tobin *Q* of the companies listed in America). The higher the index, the higher the degree of enterprise's financial constraint. The value of indicator variable is 1 if *SA* and *KZ*1997 are higher than the mean value and 0 otherwise. We repeat the regression tests again and results are shown in Table 12 which remain consistent with the main findings.

	(1) *RDSALE*	(2) *RDASSET*	(3) *Patent*
L.MB	0.001*** (3.00)	0.001*** (3.36)	0.037** (2.24)
Control	Yes	Yes	Yes
YEAR/IND	Yes	Yes	Yes
N	2023	2023	2023
R^2	0.511	0.431	0.417

Table 10. Replace the independent variable with Lag of *MB*

	(1) *RDASSET*	(2) *RDASSET*
MB	0.001*** (3.42)	
WC		0.000*** (3.03)
Control	Yes	Yes
YEAR/IND	Yes	Yes
N	3905	3905
R^2	0.442	0.571

Table 11. Replace the independent variable with *RDASSET*

	(1) *SA* = 1	(2) *SA* = 0	(3) *KZ* 1997 = 1	(4) *KZ* 1997 = 0
MB	0.001*** (2.83)	0.001 (1.47)	0.001*** (2.81)	0.001 (0.96)
Control	Yes	Yes	Yes	Yes
YEAR/IND	Yes	Yes	Yes	Yes
N	1953	1952	2917	988
R^2	0.508	0.530	0.466	0.574

Table 12. Replace the grouping variables with *SA* index and *KZ*1997 index

5.5 Use continuous variables instead of grouping variables

Considering the variable of financing constrains is continuous, to examine the listed companies' information disclosure through we-media can drive the innovation by reducing financing constraints, we employ continuous variables of financing constrains instead of grouping variables in the regression model (3) as follows:

$$RDSALE_{i,t} = \alpha_0 + \alpha_1 MB_{i,t} + \alpha_2 KZ/WW_{i,t} + \alpha_3 MB_{i,t} \times KZ/WW_{i,t} + \sum \alpha_k (Control + IND + YEAR) + \varepsilon \tag{3}$$

As shown in Table 13, the interaction terms of information disclosure on microblog (*MB*) and financing constrains variables (*KZ/WW*) is significantly positive at 1% level and 10% level, respectively, which remains consistent.

6. Further study

6.1 Comparative analysis of the sources of we-media information disclosure

We estimate model (4) to investigate the impact of the original (*MBYC*) or reposting (*MBZF*) microblogs on innovation. If the original information can drive the innovation of companies, the significance should be greater than microblog reposting.

$$RDSALE_{i,t} = \beta_0 + \beta_1 WBYC(WBZF) + \sum \beta_k (Control + IND + YEAR) + \varepsilon \tag{4}$$

Column (1) and column (2) in Table 14 present the impact of *MBYC* and *MBZF* on innovation respectively, showing that the regression coefficient of *MBYC* is significantly positive at the 5% level, while the regression coefficient of *MBZF* is not significant. Combined with the

	(1)	(2)
MB	0.001*** (3.09)	0.008* (1.84)
KZ	−0.000** (−2.11)	
MB × KZ	0.000*** (2.85)	
WW		−0.047** (−1.97)
MB × WW		0.007* (1.67)
Control	Yes	Yes
YEAR/IND	Yes	Yes
N	3905	3905
R^2	0.522	0.523

Table 13. Employ continuous variables for regression analysis instead of grouping

	(1) RDSALE	(2) RDSALE	(3) RDSALE
MBYC	0.028** (2.05)		0.040** (2.17)
MBZF		0.025 (1.22)	−0.022 (−0.73)
Control	Yes	Yes	Yes
YEAR/IND	Yes	Yes	Yes
N	2041	2041	2041
R^2	0.614	0.613	0.613

Table 14. Comparative analysis of microblog information sources

Note(s): The control variables in this table are the same as those in the previous sections and are deleted due to space limitation, the same below

regression results in column (3), in the presence of original information, reposting information cannot affect the innovation, which shows that the original microblog information can significantly drive innovation than the reposting information.

6.2 Comparative analysis of the content of we-media information disclosure

We divide the content of microblog into 12 categories (*ONE-TWELVE*) and then investigate their impact on financing constraints. *ONE-ELEVEN* belong to value related information, while *TWELVE* refers to noise information. After classification and summary, the final microblog content and its proportion are shown in Table 15.

We adopt model (5) to test the impact of *ONE-TWELVE* on innovation:

$$RDSALE_{i,t} = \gamma_0 + \gamma_1 LNONE - LNTWELVE + \sum \gamma_k (Control + IND + YEAR) + \varepsilon \quad (5)$$

As shown in Table 16, except for the third category (Marketing) and the twelfth category (Others), other categories of microblog information disclosure from listed companies are significantly and positively related to innovation, especially the fourth category (research and development), which further shows that enterprises alleviate financing constraints through we-media information disclosure and are willing to invest more capital in R&D activities.

Category	Variable name	Amount	Proportion
Performance	*ONE*	638874	8.03%
Financing	*TWO*	507721	6.38%
Marketing	*THREE*	1278166	16.07%
Research and development	*FOUR*	721924	9.08%
New product	*FIVE*	819666	10.30%
Investment	*SIX*	703031	8.84%
Reputation	*SEVEN*	568468	7.15%
Social responsibility	*EIGHT*	577727	7.26%
Corporate culture	*NINE*	585865	7.37%
Government policy-related	*TEN*	652479	8.20%
Ownership reform and corporate governance	*ELEVEN*	448315	5.64%
Others	*TWELVE*	452330	5.69%
Subtotal		7954566	100.00%

Table 15. Classification and statistics of microblog information

Variable	*LNONE*	*LNTWO*	*LNTHREE*	*LNFOUR*	*LNFIVE*	*LNSIX*
RDSALE	0.086** (2.57)	0.080* (1.76)	0.028 (1.27)	0.069*** (2.90)	0.061** (2.23)	0.062** (2.29)
Control	Yes	Yes	Yes	Yes	Yes	Yes
YEAR/IND	Yes	Yes	Yes	Yes	Yes	Yes
N	2041	2041	2041	2041	2041	2041
R^2	0.615	0.613	0.613	0.615	0.614	0.614

Variable	*LNSEVEN*	*LNEIGHT*	*LNNINE*	*LNTEN*	*LNELEVEN*	*LNTWELVE*
RDSALE	0.056** (2.09)	0.048* (1.68)	0.043* (1.73)	0.050* (1.93)	0.075* (1.96)	0.026 (1.18)
Control	Yes	Yes	Yes	Yes	Yes	Yes
YEAR/IND	Yes	Yes	Yes	Yes	Yes	Yes
N	2041	2041	2041	2041	2041	2041
R^2	0.614	0.613	0.613	0.614	0.614	0.613

Table 16. Comparison of microblog various content

Variable	LNONE	LNTWO	LNTHREE	LNFOUR	LNFIVE	LNSIX
Patent	0.106^{*} (1.68)	0.135 (1.42)	0.080^{**} (2.01)	0.101^{**} (2.45)	0.111^{**} (2.56)	0.138^{***} (3.17)
Control	Yes	Yes	Yes	Yes	Yes	Yes
YEAR/IND	Yes	Yes	Yes	Yes	Yes	Yes
N	612	612	612	612	612	612
R^2	0.410	0.409	0.411	0.413	0.413	0.417

Variable	LNSEVEN	LNEIGHT	LNNINE	LNTEN	LNELEVEN	LNTWELVE
Patent	0.096^{**} (2.01)	0.108^{**} (2.05)	0.082^{*} (1.90)	0.107^{**} (2.36)	0.074^{*} (1.88)	0.102 (1.45)
Control	Yes	Yes	Yes	Yes	Yes	Yes
YEAR/IND	Yes	Yes	Yes	Yes	Yes	Yes
N	612	612	612	612	612	612
R^2	0.411	0.412	0.410	0.412	0.411	0.409

Table 17.
Comparison of microblog various content on innovation output

6.3 Analysis of we-media information disclosure and innovation output
We use *RDSALE* and *RDASSET* to measure innovation from the perspective of innovation input. Furthermore, we can test the impact of we-media information disclosure on innovation output. In this paper, *Patent* is chosen as the innovation output variable to measure it.

We continue to use the previous microblog disclosure content to investigate the impact on innovation output. As shown in Table 17, except for the second category (financing) and the twelfth category (others), the other categories of microblog information disclosure are significantly positively related to innovation output.

7. Conclusions
Under the conditions of China's transitioning economy and emerging market, the role microblog and other we-media play in the information disclosure from listed companies should be paid more attention to. Based on the investigations above, we come to the following conclusions: (1) we-media information disclosure can promote the R&D input and innovation output by relieving the financing constraints. (2) Based on the classification of information sources, we find only the original information from listed companies can drive the innovation. (3) According to the content classification, except for marketing and noise information, microblog information can significantly improve the R&D investment of enterprises, and most of the information can also play a positive role in promoting innovation output. There is a certain difference between the content of WeChat and microblog [1]. The fundamental reason is that WeChat Official Account is a closed loop acquaintance social platform. Only those investors who subscribed the WeChat Official Account are more likely to read the articles or messages. However, the R&D information on microblog and WeChat information can significantly promote R&D input and innovation output, which suggests that enterprises can bring positive effects to innovation by disclosing information related to enterprise R&D through we-media.

The conclusion of this paper provides a reference for the listed companies to drive innovation with the help of we-media information disclosure, a new solution for the small and medium-sized listed companies in China which have difficulty in carrying out innovation activities due to financing constrains and also provides useful practical enlightenment for the government and the capital market regulatory authorities to issue relevant policies to regulate we-media information disclosure.

Note

1. Due to the limitation of space, the results of the effects of different content disclosure from WeChat official account on innovation input and output and the results of robustness are not shown. The classification and regression of WeChat are exactly the same as that of microblog. If necessary, the details can be obtained from the author.

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Corresponding author
Yani Sun can be contacted at: sunyani@stu.tjufe.edu.cn